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STREAM CHANNEL STABILITY

APPENDIX F

GOODWIN CREEK: CATCHMENT, DATA COLLECTION AND DATA MANAGEMENT

Project Objectives 3 and 4

by

E. H. Seely, E. H. Grissinger
and W. C. Little

USDA Sedimentation Laboratory
Oxford, Mississippi

April 1981

Prepared for
US Army Corps of Engineers, Vicksburg District
Vicksburg, Mississippi

Under
Section 32 Program, Work Unit 7

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PREFACE

A research watershed was selected and instrumented as part of the cooperative study on streambank stability. This appendix describes the selection process, the watershed, the instrumentation, and the data collection and processing.

The watershed selected is Goodwin Creek in southeast Panola County, Mississippi; it is a mixed land use watershed of about 8-3/4 square miles with a variety of sediment source areas. Goodwin Creek soils, geology, climate, geomorphic features, and land use are described in this appendix along with the general character of the watershed. Instrumentation has been installed on 14 streamflow sites, at a large farm pond, at several small unit-source watersheds, and at a climatological data measuring station. The rationale for the location of sites is given; the field operation is described. The data processing and management are discussed.

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) AND METRIC (SI) TO U.S. CUSTOMARY UNITS OF MEASUREMENT[1/]

Units of measurement used in this report can be converted as follows:

To convert	To	Multiply by
mils (mil)	micron (μm)	25.4
inches (in)	millimeters (mm)	25.4
feet (ft)	meters (m)	0.305
yards (yd)	meters (m)	0.914
miles (miles)	kilometers (km)	1.61
inches per hour (in/hr)	millimeters per hour (mm/hr)	25.4
feet per second (ft/sec)	meters per second (m/sec)	0.305
square inches (sq in)	square millimeters (mm^2)	645.
square feet (sq ft)	square meters (m^2)	0.093
square yards (sq yd)	square meters (m^2)	0.836
square miles (sq miles)	square kilometers (km^2)	2.59
acres (acre)	hectares (ha)	0.405
acres (acre)	square meters (m^2)	4,050.
cubic inches (cu in)	cubic millimeters (mm^3)	16,400.
cubic feet (cu ft)	cubic meters (m^3)	0.0283
cubic yards (cu yd)	cubic meters (m^3)	0.765
cubic feet per second (cfs)	cubic meters per second (cms)	0.0283
pounds (lb) mass	grams (g)	454.
pounds (lb) mass	kilograms (kg)	0.453
tons (ton) mass	kilograms (kg)	907.
pounds force (lbf)	newtons (N)	4.45
kilogram force (kgf)	newtons (N)	9.81
foot pound force (ft lbf)	joules (J)	1.36
pounds force per square foot (psf)	pascals (Pa)	47.9
pounds force per square inch (psi)	kilopascals (kPa)	6.89
pounds mass per square foot (lb/sq ft)	kilograms per square meter (kg/m^2)	4.88
U.S. gallons (gal)	liters (L)	3.79
quart (qt)	liters (L)	0.946
acre-feet (acre-ft)	cubic meters (m^3)	1,230.
degrees (angular)	radians (rad)	0.0175
degrees Fahrenheit (F)	degrees Celsius (C)[2/]	0.555

2/ To obtain Celsius (C) readings from Fahrenheit (F) readings, use the following formula: C = 0.555 (F-32).

Metric (SI) to U.S. Customary

To convert	To	Multiply by
micron (µm)	mils (mil)	0.0394
millimeters (mm)	inches (in)	0.0394
meters (m)	feet (ft)	3.28
meters (m)	yards (yd)	1.09
kilometers (km)	miles (miles)	0.621
millimeters per hour (mm/hr)	inches per hour (in/hr)	0.0394
meters per second (m/sec)	feet per second (ft/sec)	3.28
square millimeters (mm^2)	square inches (sq in)	0.00155
square meters (m^2)	square feet (sq ft)	10.8
square meters (m^2)	square yards (sq yd)	1.20
square kilometers (km^2)	square miles (sq miles)	0.386
hectares (ha)	acres (acre)	2.47
square meters (m^2)	acres (acre)	0.000247
cubic millimeters (mm^3)	cubic inches (cu in)	0.0000610
cubic meters (m^3)	cubic feet (cu ft)	35.3
cubic meters (m^3)	cubic yards (cu yd)	1.31
cubic meters per second (cms)	cubic feet per second (cfs)	35.3
grams (g)	pounds (lb) mass	0.00220
kilograms (kg)	pounds (lb) mass	2.20
kilograms (kg)	tons (ton) mass	0.00110
newtons (N)	pounds force (lbf)	0.225
newtons (N)	kilogram force (kgf)	0.102
joules (J)	foot pound force (ft lbf)	0.738
pascals (Pa)	pounds force per square foot (psf)	0.0209
kilopascals (kPa)	pounds force per square inch (psi)	0.145
kilograms per square meter (kg/m^2)	pounds mass per square foot lb/sq ft)	0.205
liters (L)	U.S. gallons (gal)	0.264
liters (L)	quart (qt)	1.06
cubic meters (m^3)	acre-feet (acre-ft)	0.000811
radians (rad)	degrees (angular)	57.3
degrees Celsius (C)	degrees Fahrenheit (F)3/	1.8

1/ All conversion factors to three significant digits.

3/ To obtain Fahrenheit (F) readings from Celsius (C) readings, use the following formula: $F = 1.8C + 32$.

1 INTRODUCTION

1.1 NEED FOR FIELD WATERSHED

One phase of a cooperative study on streambank stability between the USDA Sedimentation Laboratory and the U. S. Army Corps of Engineers, Vicksburg District required the establishment of a research watershed to test concepts developed in the study and provide data to verify models and components developed in the research. It was anticipated that grade control structures would be installed in the watershed and sufficient data collected to answer questions about the performance of the structures, about water and sediment transport, about the upstream factors affecting this transport and about the influence of all of these factors on the channel system. The underlying idea for testing was: treatment of a reach by a structural measure wasn't independent of upstream influences or of other reach treatments. Hopefully, an integrated approach which considered the basin and upstream practices as well as combinations of structural measures could be developed.

1.2 SELECTION CRITERIA

Watershed selection was based on four criteria: it should be located in the Bluff Hills draining to the Mississippi Alluvial Plain; it should be suitable for subdivision to meet the research needs of the cooperative study; it should not drain into an existing flood control reservoir; and it should be close enough to the research laboratory to allow effective guidance of the field research.

The first criteria required that the watershed be in the Bluff Hills area draining to the Mississippi Alluvial Plain. The Bluff Hills area is the location of much channel instability and sediment production problems. The Mississippi Alluvial Plain is the area of aggradation which received this sediment.

In Mississippi, the area known as the Bluff Hills (or Loess Hills) is a strip of land from 20 to 40 miles wide, east to west, stretching from the Tennessee line near Memphis, along the eastern edge of the Mississippi Alluvial Plain (locally called the Delta), to near Vicksburg then along the Mississippi River to the Louisiana state line (Figure 1). The western edge of this region is generally well-defined where the loess hills drop abruptly to the alluvial plain. The loess surface mantle thins to the east where it blends into the North Central Hills (Cross, 1974). The depth of

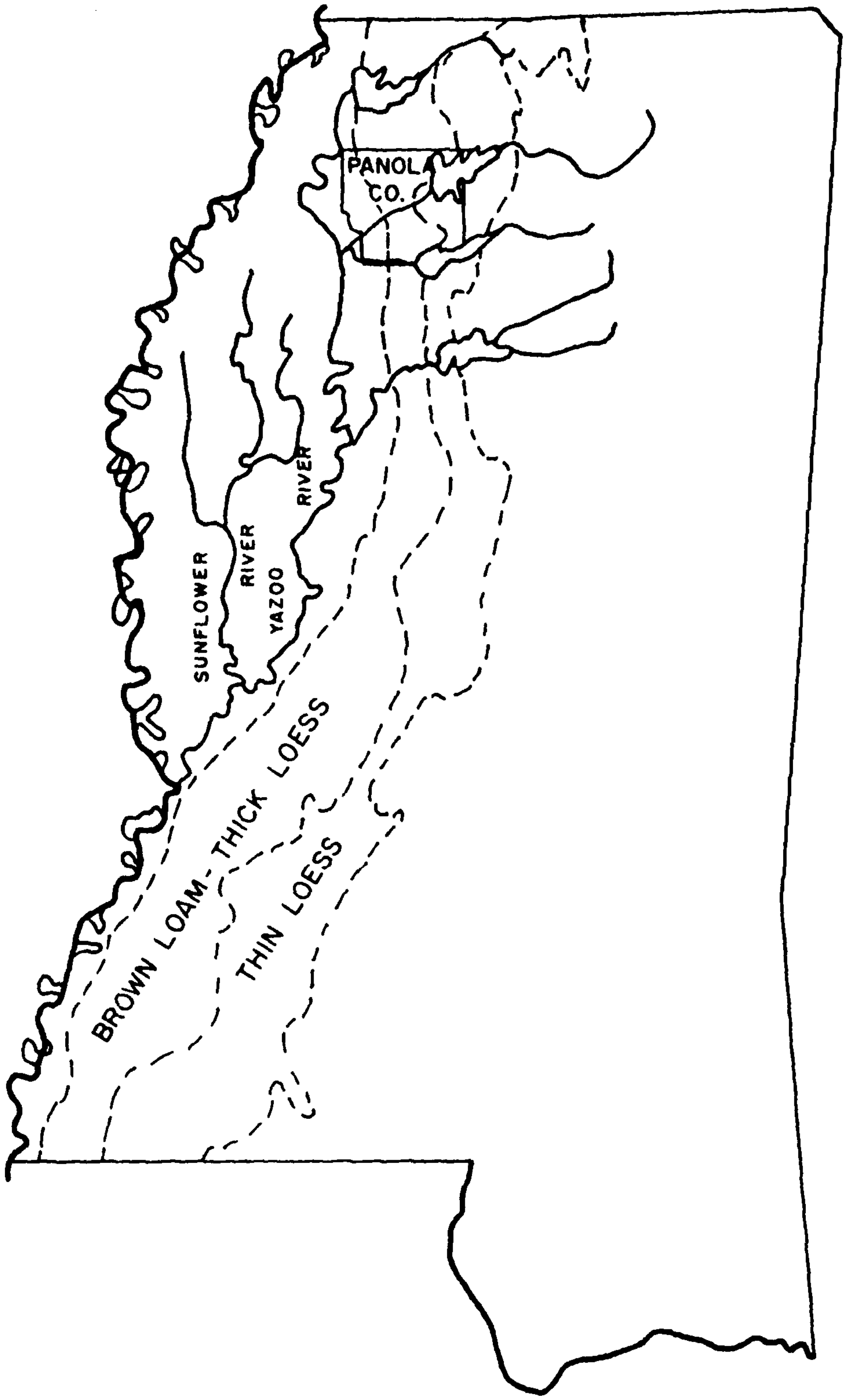


Figure 1 Location of Loess Hills Land Resource Area in Mississippi

loess in places is close to 100 feet, although the deposits in the deeper areas are more generally 30 to 50 feet in depth. The significance of this area for sediment research lies in the ready erodibility of the loess material when stripped of cover. Erosion of the Holocene valley sediments has produced deeply incised channels in the tributaries draining the bluff hills. High sediment delivery to the Mississippi Delta is creating problems for navigation. Most channels have steep sides which are unstable, contributing additional sediment and causing loss of adjacent agricultural land. The landscape is extremely dissected by these incised channels. Figure 2 shows the general soil map of Panola County, the area where the research watershed was established. Two associations, the Loring-Grenada-Memphis soils of the uplands and the Collins-Falaya-Grenada-Calloway soils of the valleys cover most of the county. The Loess Hills is a significant problem area locally and is similar to other problem areas of the United States. This similarity means findings from research in this area should have applicability in other areas.

The second selection criteria required suitability for the research needs of the cooperative study. This included several characteristics. One is diversity of land use, channel type and sediment source area. This diversity was sought to increase the amount of information that could be extracted from the field research. A watershed with primarily one type of land use might not answer questions about the effects of other types. If sediment source areas and channel types were unrepresentative in character, this information extraction would be more limited. Another characteristic was access by roads, while another was the presence of a good reach for routing. The characteristics required by this second criteria are discussed more fully in section 3.

A third criteria required location of the watershed on a stream that did not drain into one of the existing flood control reservoirs. This was a requirement of the plan of study developed under Section 32 of Public Law 93-251, "Streambank Erosion Control Evaluation and Demonstration Project".

The fourth criteria required proximity of the watershed to the research headquarters in Oxford, Mississippi. Field research must be guided from the central laboratory. The further away the watershed is, the more costly and less effective the guidance will be. Many trips to the watershed are required, thus minimizing the travel costs are important. A one-way travel time of 30 minutes to an hour was considered acceptable.

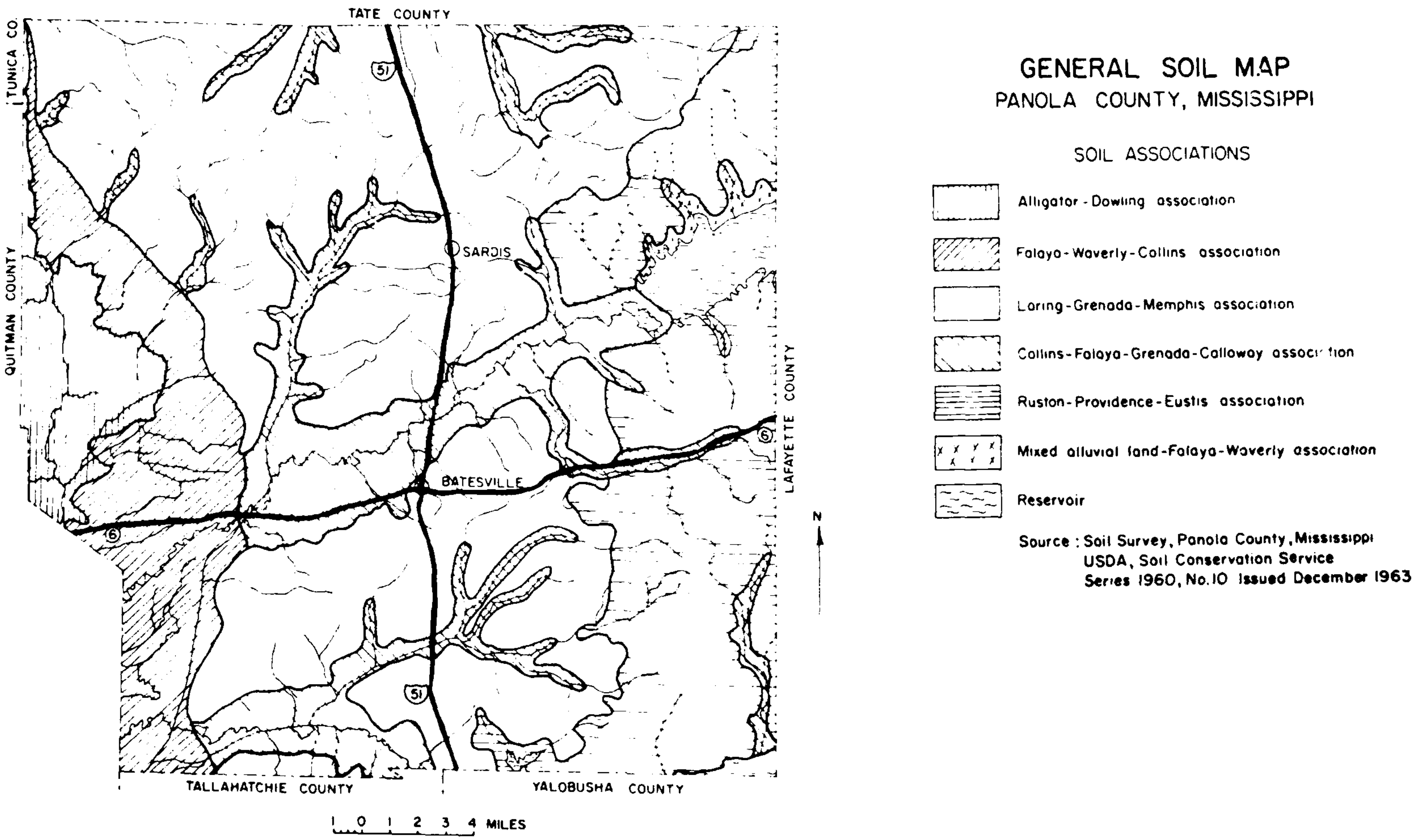


Figure 2 General Soils Map of Panola County

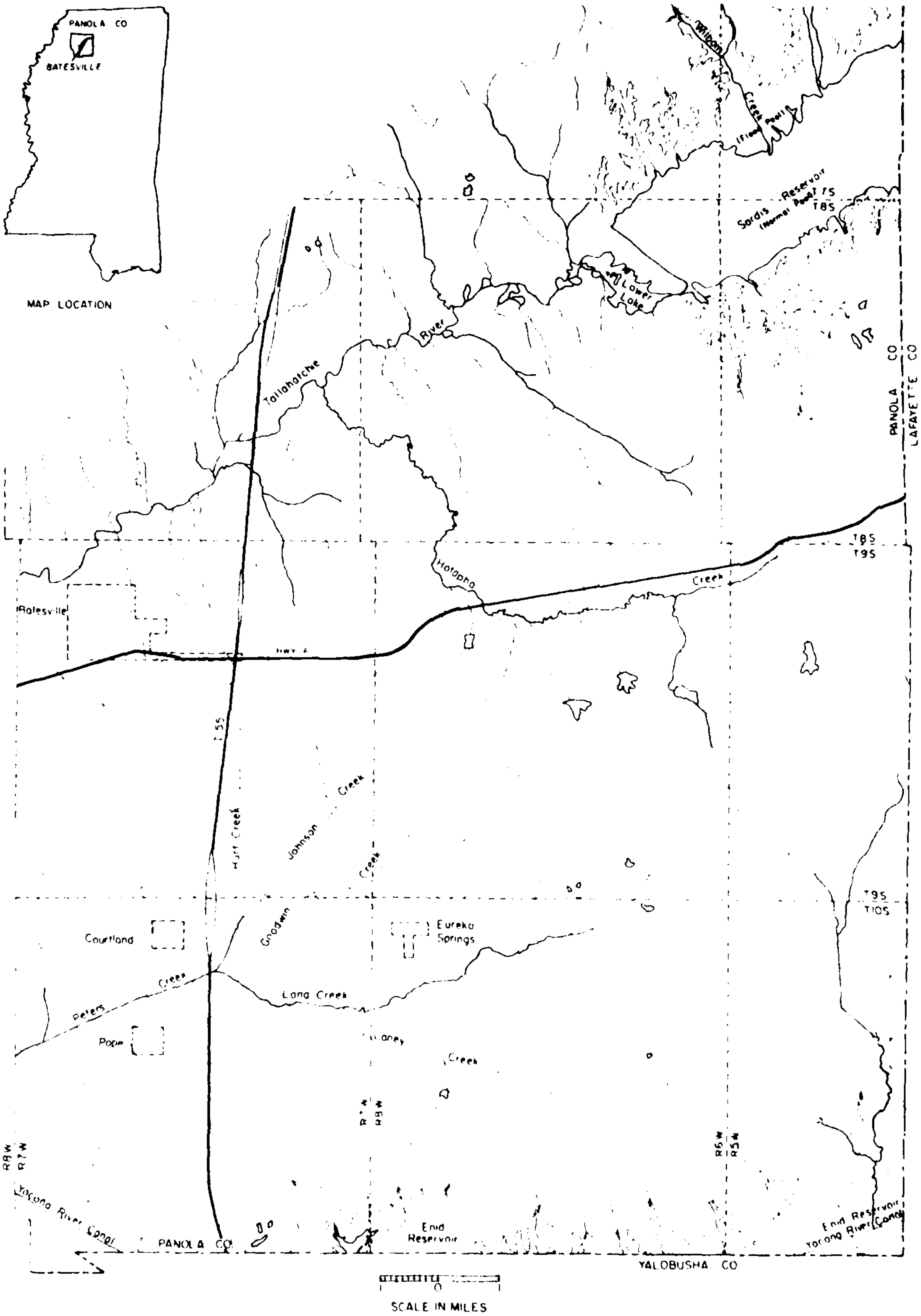


Figure 3 Southeast Panola County

As a result of these criteria, search for the watershed was concentrated in the area shown in Figure 3. This area, in southeast Panola County, lies between Sardis Reservoir and Enid Reservoir. Oxford is located 9 miles east of the Panola-Lafayette County line on Highway 6. Some searches in areas north of Sardis Reservoir and below Enid Reservoir were made but these areas were rejected because of distance from the central laboratory which would have to be traveled. The choice finally was narrowed to Peters Creek or Hotophia Creek or one of their tributaries. Extensive reconnaissance was made in the field. Hotophia Creek was eliminated because of the limited diversity of land use.

There were several tributaries in Peters Creek which were considered. Hurt Creek had poor road access and limited diversity. Johnson Creek had a long channel with no major tributaries. It could not be subdivided to create areas of different land use. Long Creek and Caney Creek were primarily timbered with little agricultural land; they had lots of gullies which would likely bias the results of a study. Goodwin Creek had the best combination of access, diversity of land use, diversity of sediment source areas, and channel conditions. Thus, it was finally selected as the research watershed.

2 PHYSICAL WATERSHED DESCRIPTION

2.1 GENERAL DESCRIPTION

Goodwin Creek is a tributary of Peters Creek which flows into the Yocona River, one of the main rivers of the Yazoo River watershed. The watershed location can be seen in Figure 3. Goodwin Creek has land use distributed nearly equally between wooded, cultivated, and pasture or idle land. The cultivated land is primarily planted to soybeans and cotton.

Figure 4 shows the topography of Goodwin Creek watershed. Goodwin Creek flows approximately from northeast to southwest. It has a total drainage area of about 8 3/4 sq. miles of which about 8 1/4 sq. mi. is gaged. The lower part of the watershed is more generally wooded. The upper portion has more pasture land. Most of the cultivated land lies along the streams on the local alluvium. However, some soybeans are grown in the uplands. Table 1 shows the drainage areas for the watershed and each of its sub-watersheds. The rationale for the division of the watershed into these subwatersheds is given in section 3. However, for convenience, summaries of watershed characteristics are given in this section by subwatershed.

The channels are deeply incised and oversized for the drainage area. In many areas the banks are vertical, bare, and subject to sloughing or undercutting. However, some reaches have banks that are apparently stable with well-established growth. Tributary channels are generally of the same depth as the trunk stream channels. Many side tributaries, of small drainage area, have depths of 10 feet or more with steep banks. The depths bear no relation to the drainage area. The cultivation of this land is made difficult by these deep channels.

2.2 CLIMATE

The climate of the research watershed is humid, hot in summer and mild in winter. Figure 5 shows the monthly distribution of average daily temperature. A nearby National Weather Service Station (Batesville, 2SW) recorded an annual precipitation of 53.5" for the period 1941-1970. Figure 6 shows the distribution of monthly rainfall through the year. Most of this precipitation occurs in winter and spring, primarily as rainfall, with very little snow or sleet. Generally the source of the rainfall is warm, moist air from the Gulf of Mexico. Summer through fall rainfall is typically from widely scattered and variable thunderstorms.

Table 1 Drainage Areas for Goodwin Creek and Its *Subwatersheds*

Watershed	Area (acres)	Area (sq. mi.)
1	5290	8.26
2	4430	6.92
3	2170	3.39
4	880	1.38
5	1060	1.66
6	298	.46
7	399	.62
8	384	.60
9	45	.070
10	15	.024
11	69	.108
12	74	.115
13	304	.48
14	403	.63
15	89	.139

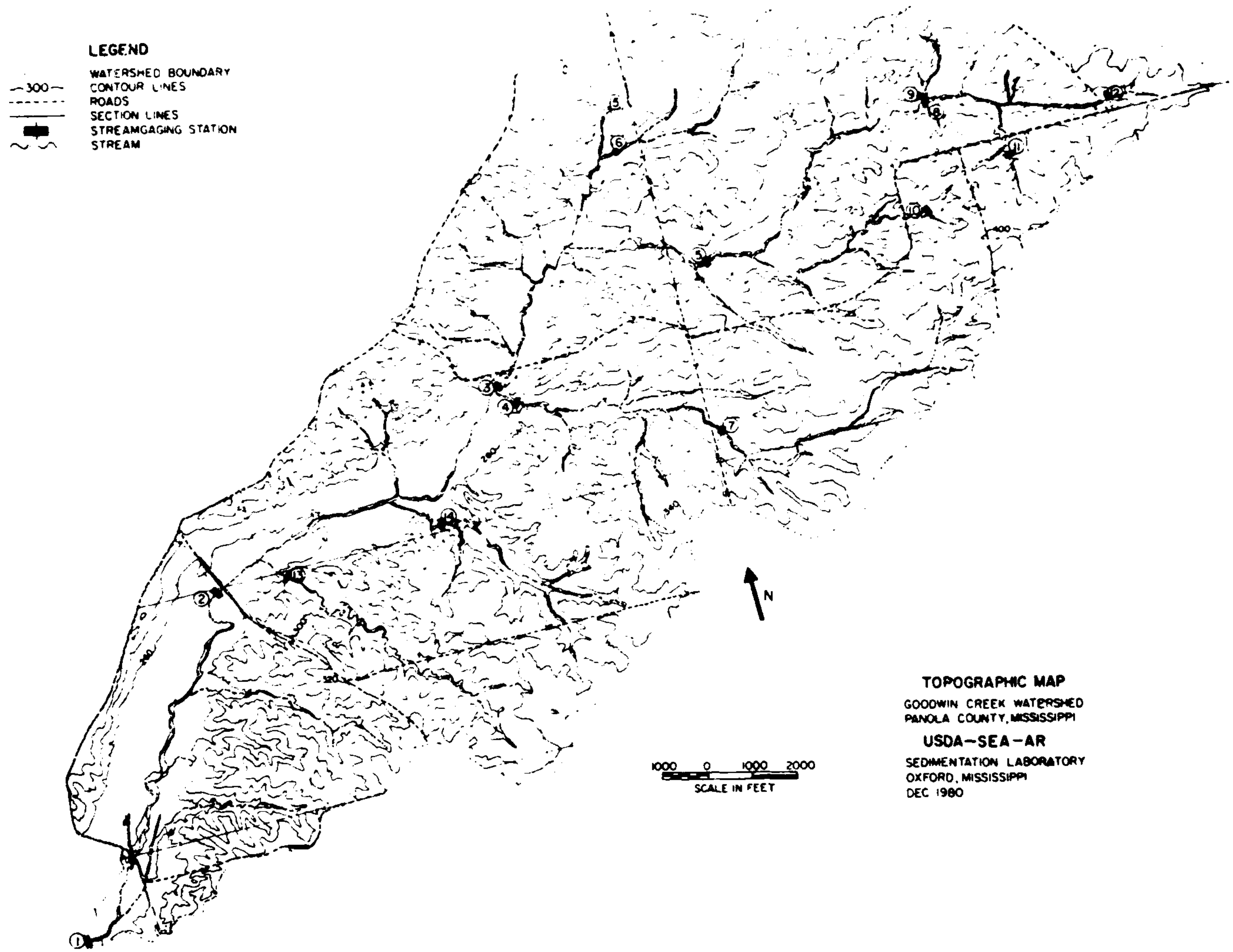


Figure 4 Topographic Map of Goodwin Creek

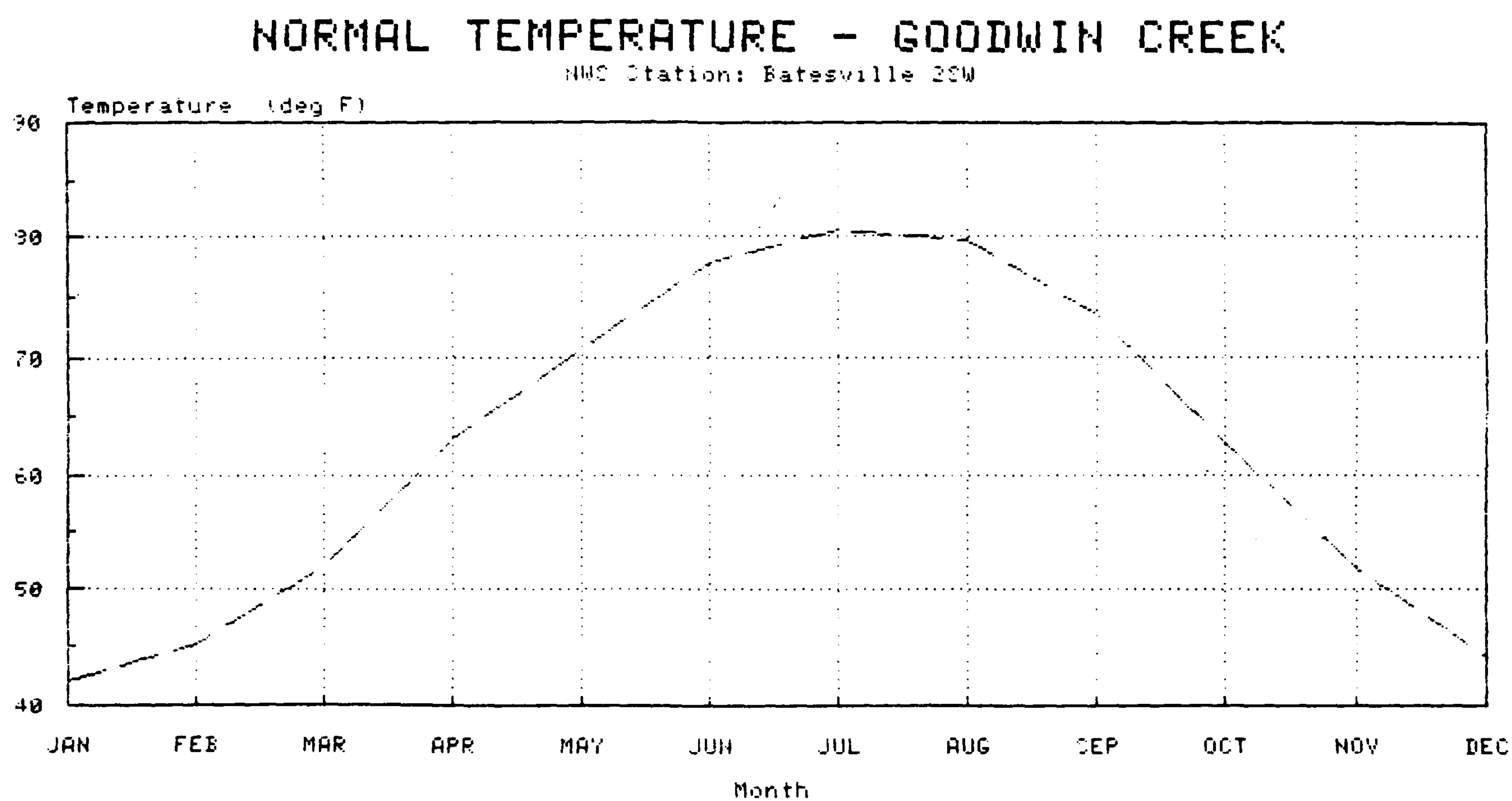


Figure 5 Monthly Distribution of Average Daily Temperature

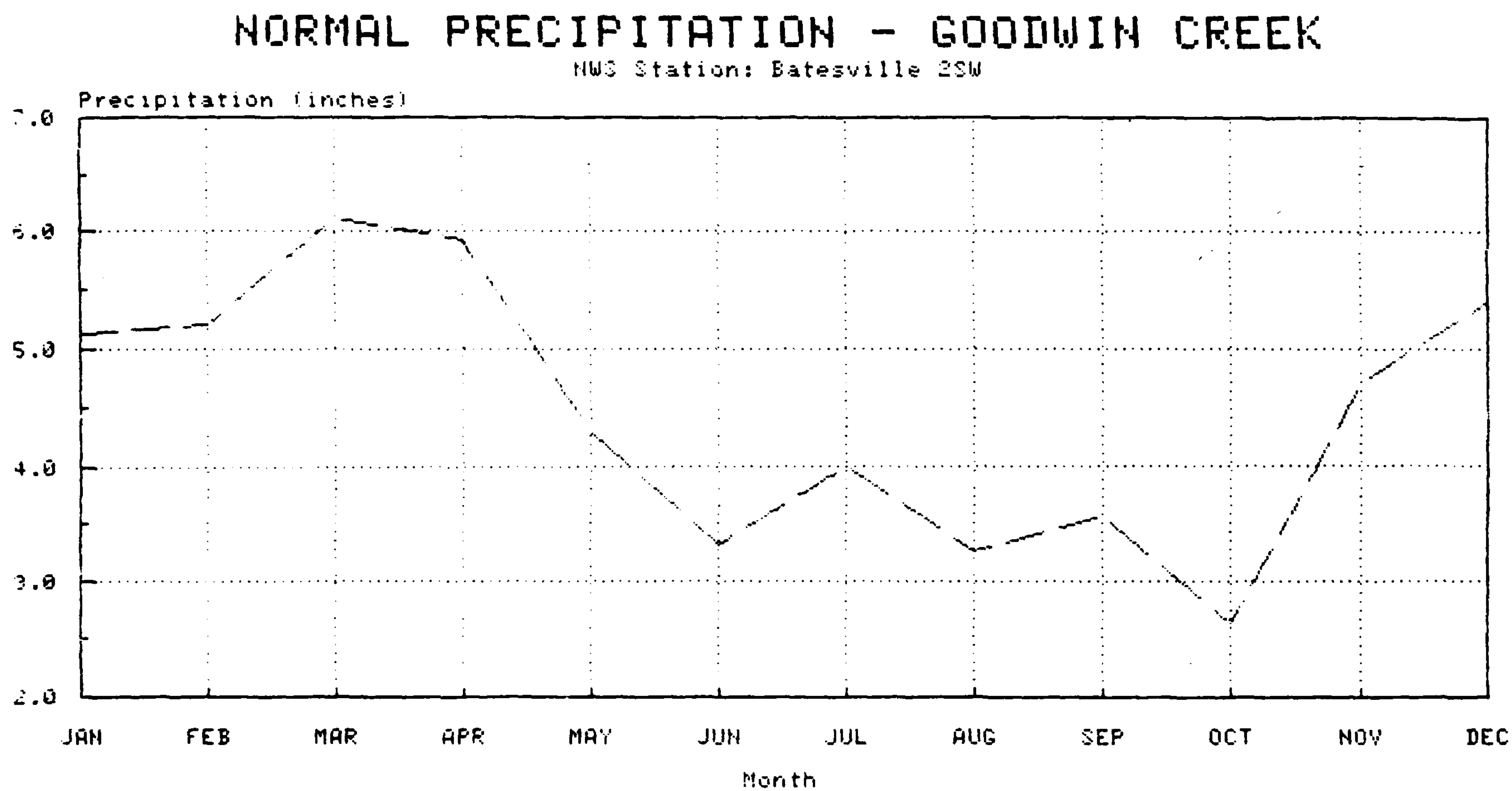


Figure 6 Monthly Precipitation - Goodwin Creek

The U. S. Geological Survey collected surface runoff data on the Little Tallahatchie River north of Goodwin Creek and on the Yocona River to the South. At these gages, both of which are below flood control reservoirs, the average annual runoff is approximately 20 inches/year. This runoff is about 40% of the annual precipitation with the remainder returning to the atmosphere as evaporation and transpiration.

2.3 SOILS

The soils of Goodwin Creek are primarily silt in texture and are quite easily eroded when the surface cover is removed. Almost all of the watershed soils erode as primary particles; there is very little aggregation. This high erodibility led to extensive gully development in the past. Some areas of the watershed show very high sediment yield as a result of these gullies.

Two major soil associations are presently mapped in Goodwin Creek. The Collins-Falaya-Grenada-Calloway association is mapped in terrace and flood plain locations. These are silty soils, poorly to moderately well drained. The Loring-Grenada-Memphis association is developed on the loess ridges and hillsides. These are well to moderately well drained soils on gently sloping to very steep surfaces. The latter association includes most of the pasture and wooded area in Goodwin Creek. The former includes much of the cultivated area in the watershed.

Table 2 lists the percent of each watershed in different soils. A soils map is shown in Figure 7. Table 3 gives descriptions of the soils as presently mapped. The descriptions and map are taken from Soil Conservation Service (1963). The survey was completed before the present classification system was fully developed. A resurvey is in progress to ensure that the soil units are accurate in relation to the current system. Soil water relations and erodibility characteristics are being determined for several of these soils. The soil water results are presented in Appendix H and those for the erodibility characterization are presented in Appendix G.

2.4 GEOLOGY

The eastern part of Peters Creek Watershed lies within the North Central Hills physiographic subprovince and partially within the Bluff Hills subprovince on the west. Peters Creek is tributary to the Yocona River which parallels the southern Panola County boundary. The Yocona

Table 2 Goodwin Creek Soil Distribution Values Are Percentage of Watershed Area in Soil Type

Watershed Number	Soil Types[1/] Ca	Cm	Co	Fa	Fl	Gr	Gs	Gu	Lo	Ml	Mn	Mx
1	5	13	5	9	*	4	1	24	34	1	4	*
2	4	14	5	7	*	5	*	27	36		2	*
3	2	22	3			7	*	27	38		1	
4	1	6	16	5	1		1	25	46			
5		22	1			9		27	40			
6		16				2		38	44			
7			28					18	54			
8		21	4			9	2	32	32			
9						13		47	40			
10		2							98			
11		13						39	48			
12		1	17			41	9	24	8			
13			2			11		40	30		17	
14	2	15						45	38			
15	6	9						2	83			

*Soil type present but less than .5% of area.

1/ Key to soil type
Ca - Calloway Silt Loam
Cm - Collins Silt Loam
Co - Collins Silt Loam, Local Alluvium
Fa - Falaya Silt Loam
Fl - Falaya Silt Loam, Local Alluvium
Gr - Grenada Silt Loam
Gs - Gullied Land, Sandy
Gu - Gullied Land, Silty
Lo - Loring Silt Loam
Ml - Memphis and Loring Silt Loam
Mn - Memphis, Natchez, and Guin Soils
Mx - Mixed Alluvial Land

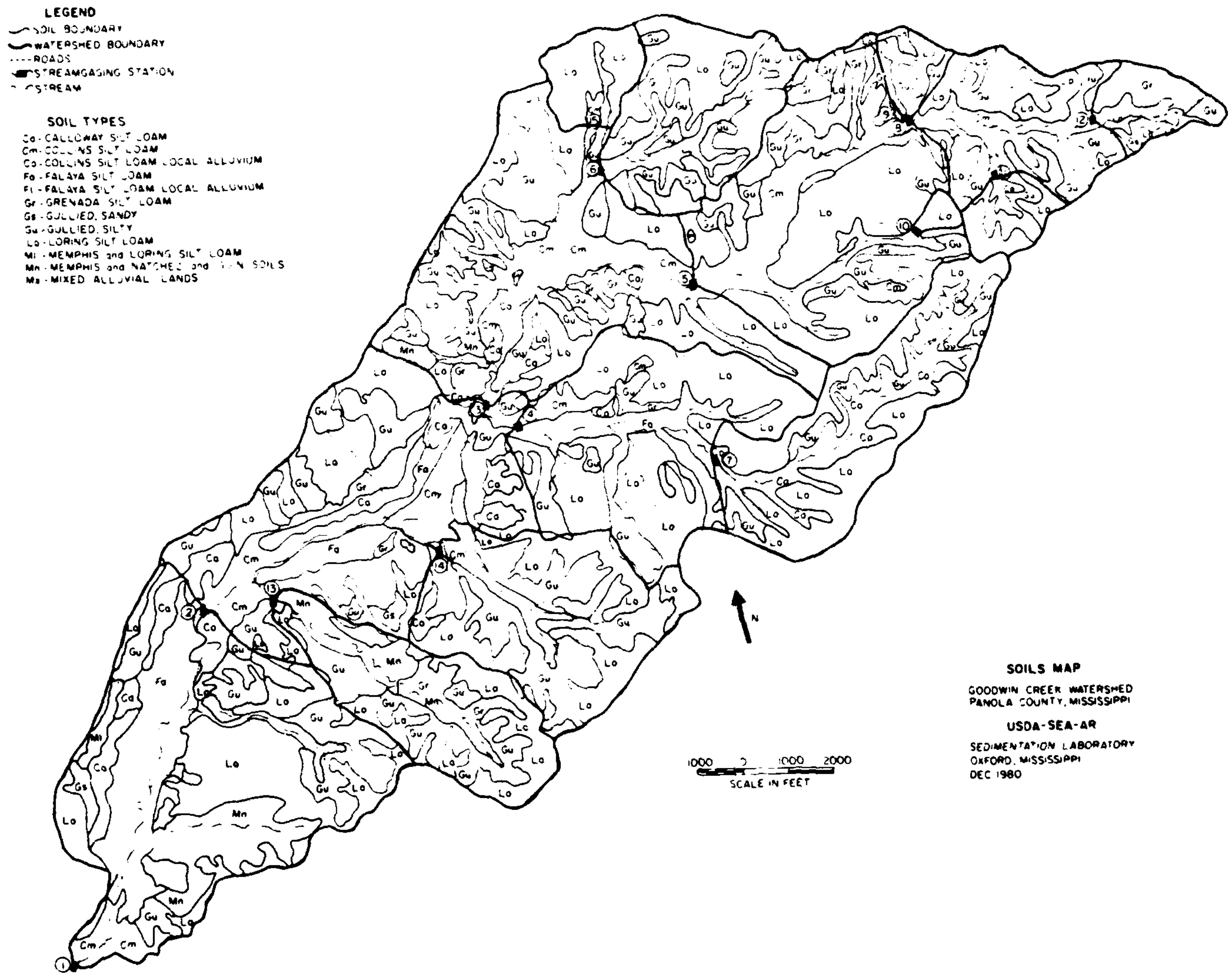


Figure 7 Soils Map of Goodwin Creek

Table 3 Soils Descriptions

Calloway Series - The Calloway series includes somewhat poorly drained, strongly acid or medium acid silt loam soils formed in deposits of loess in upland positions of low relief (terraces). A fragipan is present generally at a depth of 16 inches.

Collins Series - The Collins soils are moderately well drained, strongly to medium acid, that have formed in silty alluvium on nearly level bottom lands. These silt loam soils occur primarily along the stream in the bottom area and are the location of much of the cultivation in the watershed. Cotton is the predominant crop but has been supplanted somewhat in recent years by soybeans.

Falaya Series - The Falaya series consists of somewhat poorly drained, strongly to very strongly acid silt loam soils that developed in silty alluvium on nearly level bottom land. Most of the Falaya is cultivated.

Grenada Series - The Grenada series consists of moderately well drained, strongly to very strongly acid silt loam soils that have developed in thick loess deposits on uplands or terraces. A fragipan is present at a depth of about 24 inches.

Gullied Land - This land consists of areas that are severely eroded, severely gullied, or both. The surface soil and much of the subsurface soil has been washed away. Most of this is land that was cleared, cultivated and later abandoned. It is now in trees, idle or pastured. It is unsuited for cultivation.

Loring Series - The Loring series is moderately well drained to well drained, strongly to very strongly acid silt loam soils that developed in thick loess on uplands. A fragipan has formed at a depth of about 30 inches.

Memphis Series - The Memphis series consists of well-drained, strongly to very strongly acid silt loam soils that developed in thick loess on uplands. In Goodwin Creek this soil occurs as a mixture with the Natchez and Guin or the Loring. This series has no fragipan within the characterization depth; it is predominantly wooded.

River exits the Bluff Hills into the Mississippi Alluvial Valley about 4 miles west of its confluence with Peters Creek.

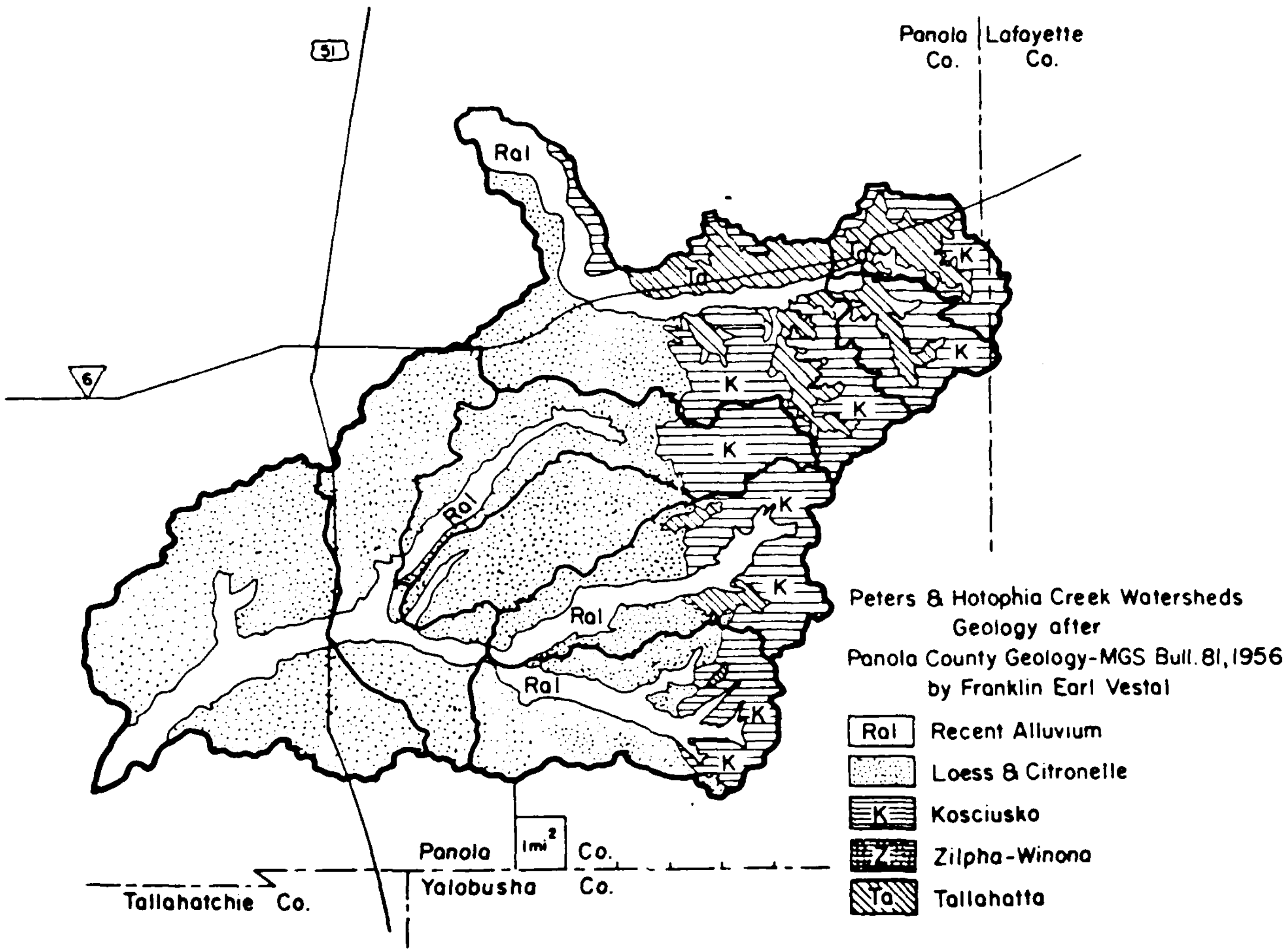
The western portion of the 87 square mile watershed is blanketed with layers of loess which thicken to the west. The eastern portion (¼) of the watershed has a thin veneer of loess which is broken more often than not by gullies and tributary channel incisions into the underlying materials. The valleys are filled with alluvium of Holocene age, mostly derived from erosion of the adjacent loess covered hills.

Cores of most hills consist of alluvial gravels and sands with scattered clay lenses. Figure 8 is a map of the geology of the area as described by Vestal (1956). Investigations by the USDA Sedimentation Laboratory over the past four years have determined that the material shown as Eocene in the eastern portion of the map is actually much younger alluvium (Appendix E). This entire geologic assemblage lies above a regional erosion surface developed on Tertiary marine shales & mudstones. The only ages that can be assigned to the alluvial sands & gravels in the cores of the hills at this time are post-Eocene but older than 700,000 years. The loess caps on the hill crests are of Peoria, Roxana, and Loveland ages. Most of the soils and paleosols that control channel bank stability in the valleys are derivatives of these loess materials although some portions are derived from the sands and gravels. The alluvial material in the valleys occurs in the same predictable stratigraphic sequence of lithologies throughout the entire area and is therefore probably the result of regional paleoclimatic conditions. These alluvial deposits are discussed in section 2.5 of this appendix and described in detail in Appendix E.

2.5 GEOMORPHIC FEATURES

The channel system of Goodwin Creek is well incised into the watershed surface and is influenced by the valley fill deposits. Eight valley-fill deposits have been identified. Deposits are, from youngest to oldest (surface to increasing depth): (1) post-settlement alluvium, (2) young paleosol, (3) channel fill, (4) old Paleosol, (5) channel lag deposits, (6) bog-type materials, (7) two poorly defined late-Quaternary fluvial deposits, and (8) consolidated sandstones. Postsettlement alluvium, produced in historic times largely by man's activities, overlies the young paleosol, and old paleosol materials. The young paleosol materials include

Figure 8 Geologic Map of Peters Creek



both vertical and lateral accretion deposits which are less intensively weathered than are the old paleosol materials. Deposition of young paleosol materials began about 3,000 years Before Present (yr BP). Channel fill deposits, about 5000 yr BP in age, are coarser-textured relatively weak materials. Old paleosol materials are vertical-like accretion deposits, probably deposited during times of restricted surface drainage and low flow velocities. These materials are highly weathered. They were deposited immediately after deposition of the bog or channel lag deposits, both of which were deposited about 10,000 yr BP. These two deposits are both fluvial deposits reflecting differing energy regimes. The coarse-grained channel lag deposits appear to be primarily point-bar deposits whereas the fine-grained bog-type materials may represent deposits which accumulated in separation zones downstream of bendways or large bars which accumulated in channel cutoffs. Two deep organic deposits have been sampled but at this time are poorly defined. Both occurred in the eastern-most part of our study area where the consolidated sandstone was absent. One sample at a depth of 55 feet was dated at 34,900 yr BP and the second at a depth of 45 feet was dated at 17,000 yr BP. Consolidated sandstones occur as discontinuous bodies representing scattered remnants of one or more sedimentary units older than 40,000 yr BP. A total of 115 samples have been dated thus far.

The nature and chronology of these deposits and their fit with the paleoclimatic record indicate that the dominant control of the valley-fill sedimentary system was paleoclimatic with concurrent base level controls. In this scenario, late-Wisconsin times were characterized by widespread stream incision controlled largely by pluvial conditions and by low base levels. This interpretation is based upon the relative paucity of pre-Holocene organics, the extreme depth of the few organic samples older than Holocene and the presence of mid- to late-Wisconsin loess capping of present-day valley terraces. As the late-Wisconsin glaciation waned and sea levels rose, valley degradation ceased and aggradation began. As the post-glacial pluvial condition evolved, fluvial deposits became more prevalent and are preserved as the channel lag and bog deposits (about 10,000 yr BP in age). Tributary valleys rapidly became plugged, inducing deposits of old paleosol materials. The source of these sediments was the interfluve loess. Valley aggradation ceased as the climate became drier.

This condition persisted until about 3,000 yr BP. Channel incision into or through the old paleosol was initiated by increased precipitation at this time and young paleosol materials were deposited as a normal consequence of channel meandering.

Four of these valley-fill stratigraphic units influence channel stability and morphology. The youngest of these units, the post-settlement alluvium (PSA), functions as a loading term for gravity-induced failure of either of the underlying paleosols. The next youngest of these units is the young paleosol, a relatively unweathered fluvial deposit. Failure of the young paleosol material results primarily from gravity stress, and is accentuated by the development of vertical tension cracks parallel with the bank. The tension crack development is undoubtedly related to the relatively unweathered and, hence, isotropic nature of this silty material. Old paleosol materials underlie the young paleosol and/or historic sediments. They are highly weathered and are typified by a well-developed polygonal structure which controls the mode of bank failure. The polygonal seam materials have minimum stability, and block-type failure is induced by gravity stress. In general, the old paleosol materials are more stable than the younger materials. Gravel and/or sand deposits underlie the old paleosol. These deposits are usually unconsolidated but are occasionally cemented by iron, forming bed-control sills where they crop out in the channels. Exposure of the unconsolidated materials in a bank toe position, resulting from vertical degradation, typically increases rates of failure due to gravity stress.

The present-day channel morphology in northern Mississippi has been largely determined by the presence or absence of the iron-cemented bed control sills. Where such sills are absent, such as in Johnson Creek, a tributary of Peters Creek, thalweg lowering progressed to a sufficient depth to expose the unconsolidated gravels and/or sands in a bank toe position. For this condition, gravity forces become the limiting stress for bank stability. Thalweg degradation started at least 40 years ago and progressed upstream in the form of either a diffuse or discrete headcut. Channel width-to-depth ratios are coherent upstream of the headcut where the channel bed material is either of the cohesive paleosols. Downstream of the headcut, however, Johnson Creek is a sand-bed channel. Width-to-depth ratios are random downstream of the headcut, resulting from excessive

channel widening particularly in young paleosol materials. Where iron-cemented sills have prevented vertical degradation, such as in Goodwin Creek channel, a gravel-bed tributary of Peters Creek, excessive lateral channel erosion has occurred. This widening is not constant throughout the system but appears to be associated with local stratigraphic and/or channel morphometric conditions. Channel width-to-depth ratios are functions of channel features such as the presence or absence of bed control sills or large bendways. See Appendix Chapter E for further discussion of these features. Selected reaches in both channels have widened excessively since 1968.

In summary, the energy expenditure within the channels has not been uniform over relatively long channel lengths but has been concentrated in relatively short reaches of the channel. As illustrated for Johnson and Goodwin Creeks, this form of degradation is intimately associated with the nature and distribution of the valley-fill stratigraphic units of Holocene age. Channel morphology and channel morphometric changes are similarly intimately associated with these Holocene units. Gravity stresses limit bank stability for channels which are presently incised. The magnitude or rate of failure ultimately depends upon the ability of the flow to remove the slough from the bank toe position. Slough from either of the paleosols and from the postsettlement alluvium is easily removed, regenerating the failure process.

2.6 LAND USE

The drainage area of Goodwin Creek is composed entirely of rural-agricultural lands. There are no incorporated towns or villages in the watershed. Farm homes and rural residences are distributed throughout the area. Most of the roads are gravel but passable throughout the year.

Cotton and soybeans, the principle agricultural crops in the area, are grown on most of the agricultural lands. Comparatively smaller acreages of corn and small grains are planted each year. Most of the cultivated land is located in creek bottoms and on relatively flat uplands. Pasture and forest lands are usually located on moderate to steep slopes and on severely eroded uplands.

A general land-use map of the Goodwin Creek drainage area is shown in Figure 9. Four broad land-use classifications - cultivated land, pasture, forest, and idle land are shown. Land not being used for crops, pasture,

or forest at the present time, 1980, was placed in the idle category. Land use for the Johnson Creek watershed is essentially the same as Goodwin Creek.

The map was prepared to show a general picture of land use. Watershed and field boundaries are only approximately correct and should not be used for determining watershed and field areas. Not shown are approximately 90 farm ponds which exert some hydrologic control over a significant portion of the watershed. Active sediment producing gullies occur throughout the watershed but the number and aerial extent of these has not been determined. Table 3 summarizes the approximate percentage breakdown by subwatershed.

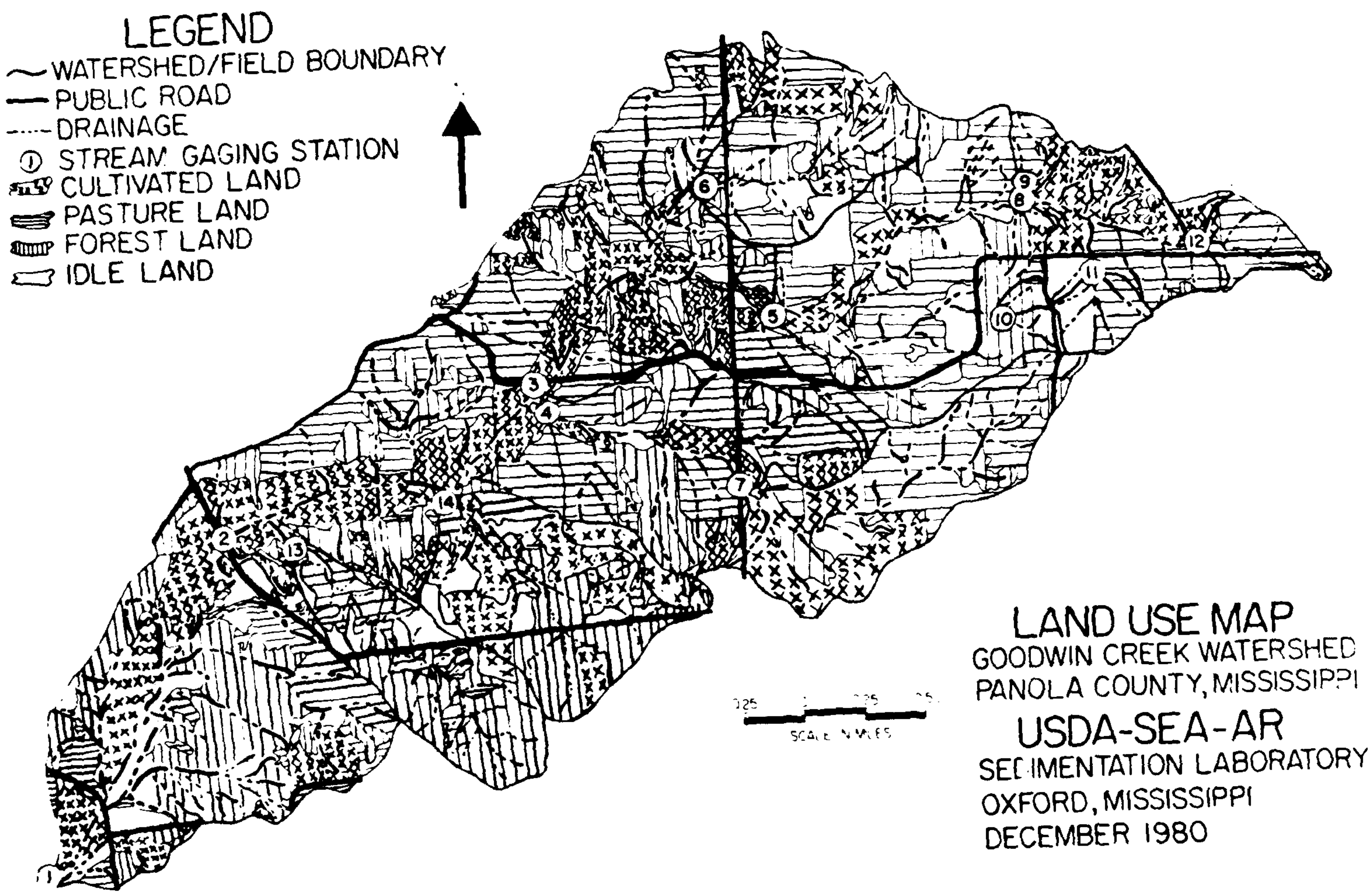


Figure 9 Land Use Map of Goodwin Creek

Table 4 - Goodwin Creek - Land Use Distribution by Subwatershed

Watershed	Idle (%)	Wooded (%)	Pasture (%)	Cultivated (%)
1	8	27	30	35
2	7	26	31	36
3	8	21	33	38
4	2	21	41	36
5	10	20	35	35
6	8	28	30	34
7	3	4	56	37
8	16	3	48	33
9	10	60	30	0
10	0	100	0	0
11	69	7	24	0
12	0	0	83	17
13	24	49	27	0
14	4	43	6	47
15	22	0	0	78

3 DESIGN OF HYDROLOGIC DATA NETWORK

The design of the data network was dictated to a large extent by the nature of the research to be conducted. In the reconnaissance for selection of the watershed, this research need was a part of the criteria. These criteria which are related to the specific research needs are described below, they are described more fully in the research proposal (USDA Sedimentation Laboratory, 1977).

The criteria required:

1. A reach at the lower end should be available for routing studies. This reach should have *no major tributaries entering.* The channel should be well defined and should itself be an important source of sediment production. This reach should be isolated by streamflow measuring stations at each end which measure continuously streamflow (as stage), water temperature, and, to the extent possible, total sediment discharge.
2. The drainage area above the reach should be subdivisible by streamflow measuring stations into subcatchments which are relatively homogeneous or which isolate significant sediment source areas or channels of differing stability. The homogeneity should cover land use, soils, and geology as much as possible. The differences between the subcatchments should be significantly greater than the differences within the subcatchments. The areas isolated should reflect the major land uses in the catchment.
3. Where gages are in tandem or the watersheds are nested, the subdivision should isolate major tributaries and leave less than half of the intervening area ungaged.
4. The locations should have reasonable access for construction and maintenance.
5. The watershed should have minimal urbanized area.
6. The location of streamflow measuring sites were to be located at grade control structures to take advantage of the opportunity to use them as flow measuring devices.

The process of subdivision of the watershed according to these criteria can be best illustrated by noting Fig. 10, which shows the location of the flow measuring stations. The reach for routing was isolated by stations 1 and 2. This reach has little major inflow and is a

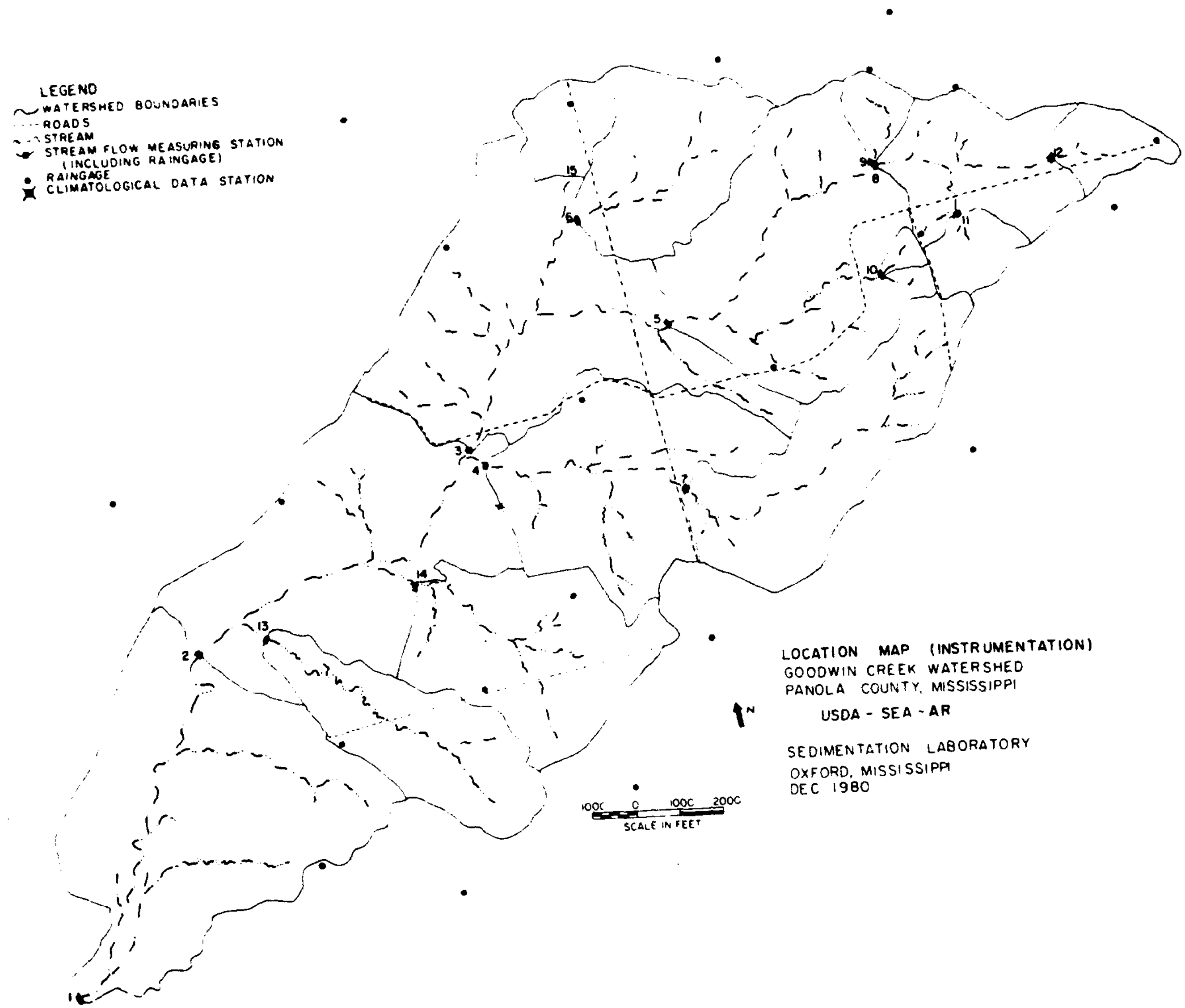


Figure 10 Instrumentation Location Map of Goodwin Creek

significant sediment source area itself. Station 1 was located about as far downstream as feasible. Much further and it would be affected by backwater from the confluence with Long Creek. Station 2 was located just downstream from a road which gave convenient access. Just upstream of the road the channel changed in character to a more stable regime.

Stations 3 and 4 were established upstream of station 2; these upstream stations isolated the two major tributaries above station 2. Stations 13 and 14 split off two smaller tributaries above station 2. However, the primary reason for adding 13 and 14 was the character of the channel bed; these two streams are primarily gravel bed.

The drainage area above stations 3 and 4 were further subdivided by three additional stations located along a paved road crossing the watershed. These three stations were 5, 6, and 7. Above station 3, a large farm pond was instrumented; this pond is referred to as station 15.

Stations 8 and 9 were located above station 5. Station 9 isolates an area that was formerly cultivated and is gullied. It is a major contributor of sediment and represents significant area that is in similar condition. Station 8 was located at the same point on the main channel as a convenient point to subdivide the area above 5. The same road and data collection station could then serve both 8 and 9.

Station 10 was established on a small area that was totally wooded; this area serves as a unit-source area for wooded land use. Station 11 was established at a site that is almost entirely pasture or idle land. Station 12 splits off the very upper end of the watershed. Below station 12 the channel changes dramatically in size and depth.

Several small unit-source watersheds are to be established on areas that represent single land uses on cultivated areas, such as cotton and soybeans. These areas will each be several acres in size. The drainage area, soils, and land use distributions of the subwatersheds are summarized in tables 1, 2, and 4. Figs. 7 and 9 show the soil and land use distribution.

The measurements needed in the research watershed included variables which directly estimate or affect the rate and volume of runoff, rate and amount of sediment production and sediment size distribution. These variables included water level or stage in conjunction with discharge measurements to develop stage-discharge ratings. Sediment concentration in

the stream was to be measured with a density cell; samples were to be taken for analysis to determine particle size distribution. Other variables to be measured which affect or determine flow and sediment rates included rainfall (intensity and amount), temperature (air and water), land use, tillage practices, soil type, slope of the land surface, and soil moisture. Measurements of other needed climatological variables include: evaporation, wind speed and direction, solar radiation, soil temperature, relative humidity, and barometric pressure. Surveys of stream channels to determine the rates of channel aggradation and degradation were also to be made.

As noted, the streamflow measuring stations were located at grade control structures; and the structures were designed to have useful hydraulic properties for flow measurement. These were designed as supercritical flumes, primarily because of the high sediment loads in Goodwin Creek channels. A typical structure and its use for flow and sediment measurement is described in Appendix A, Section 3. The supercritical flumes were expected to pass the sediment without deposition in the measuring structure, which some measurement structures such as weirs do not accomplish. An approach section, a measuring section with bottom slope of approximately 4%, and an energy dissipation basin are the 3 main features of each structure. The approach section ties the bank to the straight sides of the measuring section. The sides of the approach section are curves which become tangent to the measuring section where they are joined. The measuring section is triangular in cross section with side slopes of 1 on 2 on structures 4-9 and 11-14. Structures 1-3 and 10 have a floor with side slopes of 1 on 5 and walls with side slopes of 1 on 2. The floor on the larger downstream stations, was needed to fit the structure into the channel and still provide the desired hydraulic characteristics. See Appendix A for a more complete description of the structures.

Instrumentation at each streamflow site includes a set of recorders to measure the water level in the flume measuring section and downstream in the energy dissipation basin, a weighing, recording raingage, water and air temperature sensors, a flow through density cell, an automatic pumped sediment sampler and soil temperature sensors. The automatic sampler is a Chickasha pumping sampler which can be obtained through the Interagency

Sediment Project at St. Anthony Falls Hydraulic Lab. in Minneapolis, Minnesota. The sampler will hold up to 28 samples with each sample approximately 1 liter in volume.

The density cell selected is a Dynatrol[1/]. The purpose of having a density cell is to have a continuous record of sediment concentration. In the density cell, the water sediment mixture is pumped through a vibrating "U" tube which has a voltage output approximately proportional to the concentration of the mixture.

The data acquisition system was chosen by considering three classes of systems. These were the traditional "courier" system, a magnetic recording system, and a telemetry system. The "courier" system is one in which observations are made and recorded by hand or a chart is collected periodically by an observer in the field. This system uses the simplest technology and is the least complicated. It is labor-intensive relative to the amount of data collected. Data must be reduced to a computer readable form. Digitizing the data can be quite laborious and time consuming if many charts are collected; errors are frequent.

The magnetic recorder system records sensor output as an electrical signal directly onto a magnetic media such as cassette tape. This system has more complexity than the courier system but has the advantage of not requiring the digitizing step. Some processing and editing of the data are usually required, but the data is on a computer readable media when collected. A big disadvantage is that it may not be obvious that something is wrong with a sensor until the entire record has been scanned.

The third class considered was the telemetry system. This class of systems have the greatest complexity of the three but also offered potential advantages which were considered quite worthwhile. These advantages included: real time access to the data, synchronization of data time over the entire research watershed, and ability to take a high intensity of observations. Several telemetry options were examined with VHF radio telemetry being selected. The selected system works with automatic periodic polls (or transmit-data-requests) at thirty minute intervals from a central computer in the laboratory to data collection

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[1/] Trade names are given for informational purposes only and do not imply endorsement by the U. S. Department of Agriculture.

stations in the field. These polls cause the data collection stations which are micro-computers to transmit stored data via radio. The data collection stations are able to store up to 30 minutes of data collected at 1 minute intervals on all sensors. Sixteen sensors can be read on most of the data collection stations. The central computer can transmit manual polls to any station and sensor. This permits the observation from the laboratory of the watershed state and facilitates more effective maintenance.

4 WATERSHED OPERATION

There are two phases of watershed operation discussed here, instrument installation and field data collection. Instrument installation is an on-going phase. Table 5 summarizes the current status of installation for planned stations and sensors. As the research program continues, additional types of data may be collected. The field data collection has been concurrent. It has not been practical or desirable to try and complete all instrument installation before beginning field data collection.

4.1 INSTRUMENT INSTALLATION

The construction of the grade control/flow measuring structures began in 1978 and was completed in 1980. As a structure was completed, work was begun on an instrument shelter to house a stage recorder, a pumped sediment sampler, a density cell, and a data collection station. The shelter was constructed at the site of plywood and 2" x 4" lumber and was given a tin roof.

Where possible, the instrument shelter was constructed over the gage wells. This allowed the connection between the stage recorders and the data collection station and between the stage recorder and the pumped sediment sampler to be made in the dry. It also allows the observer working on the recorders during bad weather to work inside.

The density cell and pumped sediment sampler are being installed in series. The water and sediment pumped from the stream goes first through the density cell then through the waste line of the Chickasha sampler. When the stream depth is above a preset stage, a pump is turned on and pumps continuously while the stream is above that stage. With water being pumped continuously through the waste line of the Chickasha sampler, obtaining a sample only required activating the splitter. An air trap has been installed in the sample line just ahead of the density cell to eliminate air bubbles which affect the density cell output. The installation in series gives some redundancy in that the density cell measures what is collected in the Chickasha sampler. However this redundancy is useful now. The density cell has zero drift of uncertain characteristics and needs checking to remain confident at the calibration. The pumped sampler collects data less frequently. The density cell record

Table 5 Goodwin Creek Data Collection Summary

A. Flow measuring stations

Data type	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Depth of flow	M	X	X	X	X	X	X	X	M	X	M	X	M	M
Precipitation		X	X	X	X	X	X	X		X		X		
Density cell (sediment conc)		X	X	X	X	X	X	X				X		
Pumped sediment samples		X	X	X	X	X	X	X		X		X		
Water temperature		X	X	X	X	X	X	X		X		X		
Air temperature		X	X	X	-	-	-	-		-		X		
Soil temperature		X	X	X	X	X	X	X		X		X		

X Data collection electronically

M Data collection by chart

\- No sensor planned

B. Climatological data station (Site 50)

1. Standard precipitation
2. Ground level precipitation
3. Wind speed
4. Wind direction
5. Humidity
6. Barometric pressure
7. Air temperature
8. Evaporation pan level
9. Evaporation pan - wind speed
10. Evaporation pan - temperature
11. Solar radiation

can be used with the pumped sample analysis to give a more complete picture of sediment variation through a storm event. Ultimately, the arrangement may be changed so that the density cell and pumped sampler sample different sources.

The intake for the sediment sampling line has been mounted in several different places. The testing was started on the lower stations, primarily station 2 which has a high sand load. The intake was first mounted in the bottom of the flume near the upper end of the throat. The intake kept plugging so it was moved up the side of the flume about ½" and a little further downstream. This was to try and escape a wedge of sediment which lies in the entrance of the flume and seems to contribute a lot to the intake. When the intake continued to plug, it was tried at 1.0 depth. This worked as far as missing the heavy load of sediment moving close to the bottom, however it was felt significant flow might be missed. An alternative is to be sought which will be lower in depth but will not plug up because of heavy bedload.

Other instruments installed at each site include thermistors to measure water, air, and soil temperature. The water temperature is measured just below the flume in the energy dissipation basin. The soil temperatures are measured in the enclosure containing the instrument shelter, usually at 2", 4", and 20" depths. Air temperature is measured in a standard louvered shelter in the same enclosure. A weighing recording raingage measures rainfall within several hundred feet of the data collection station. The raingage was installed to be free of surrounding obstructions yet close enough to be connected to the data collection station. A network of approximately 26 additional raingages has been installed over the watershed to give complete area coverage. These gages are not on the telemetry system.

A climatological data station has been installed near the center of the watershed. The site, in an open pasture area, is installed in a 100' x 100' fenced enclosure. Within the enclosure a standard weighing recording raingage has been installed. Approximately 15' away, an identical type raingage has been installed with the mouth of the raingage at ground level by mounting the gage in a covered pit. A standard louvered shelter contains sensors to measure relative humidity, barometric pressure, and air

temperature. A pyroheliometer is used to measure solar radiation. Instruments to measure wind direction and velocity have been installed at 2 meter heights. An evaporation pan has been installed within the enclosure.

Installation of eight of the twelve data collection stations is now complete. Data collection at the remaining stations is manual. A major problem contributing to delay in installation has been the need to install protective devices. Although the antenna at each station was grounded, high voltage was still able to enter the data station, apparently over sensor wires. Several severe failures of stations resulted with the loss of a number of integrated-circuit boards each time. An extensive protection package had to be installed at each station. This package consisted of two units in series on each line going to the data station. One unit was a gas discharge tube to handle very high voltages; the other unit was a low voltage protection device to handle smaller remaining voltages which would still have harmed the system. The combination has proven effective, so far, in protecting the system from voltage extremes.

4.2 FIELD DATA COLLECTION

The field operation of the research watershed involves several phases after the instrument installation is complete. These include the routine servicing of the instruments, storm duty, handling special problems, and supplemental data collection by a field observer.

The routine servicing of instruments is performed weekly. At each station, the charts are changed and edited on the water level recorders and raingages. Problems found at that time are fixed. Periodically, or when the need is indicated, new calibrations must be made. The pumped sediment sampler is checked. The flume section is checked for any problems which might affect flow measurement accuracy. The intake plate for the gage well must be clear with the slots open. Routine discharge measurements and hand sediment samples are made if needed. Batteries may need to be replaced for some instruments.

During storm events, discharge measurements are made, sediment samples are taken, and instruments checked. Discharge measurements are necessary to verify the theoretical calibration which required estimates of resistance coefficients. With the field measurements, the resistance coefficients can be estimated directly and greater confidence placed in the

ratings. Sediment samples are taken by hand across the measuring section in the flume. These samples are more representative of the transport than the pumped samples because they are taken at equally spaced locations across the flow and sample almost the entire depth at each location. The hand samples can then be compared with the pumped samples and density cell readings which sample from a fixed point in the stream but can be taken more frequently. Storm duty also involves verifying that instruments are working so that data will not be lost at a critical time.

Special problems which can occur in a research watershed are many and varied. They include problems with instrumentation. Intakes can plug up; trash can be caught in an intake. Problems can occur that are not instrument related. Access roads can wash out; drainage or washing problems can occur at sites. Vandalism to instruments has occurred at times.

Some data must be collected that cannot be instrumented. This data is collected periodically by the field observer, often in conjunction with the maintenance visits to a site. Examples of such data collection include: stage levels in farm ponds, land use surveys, and channel surveys.

5 DATA REDUCTION AND EDITING

The data are brought from the field to the laboratory in a variety of forms, as traces on a chart, map notations, radio messages, or observations in a notebook. To be readily usable the data must be converted to digital form, reduced, edited, and stored on a computer. Much of the data comes directly from the field in digital form, as radio signals. Data from non-telemetered raingages are obtained as charts. These data are converted to digital form on a digitizer. Data from water level recorders and from raingages at telemetry sites are also recorded on charts as back up for the radio transmitted data. These charts are also digitized as needed to fill in any gaps when the telemetry system is not working. Some data such as field surveys are keyed directly from field notebooks into the computer.

Much of the data that is telemetered has reached the lab as a digital form of an electrical signal. Conversion to equivalent real units is necessary before further processing. Calibrations of each field sensor are made by the field maintenance technician when the sensor is installed. This relationship is stored on computer and used to convert the electrical signal to appropriate units.

Data from nontelemetry sources are merged with the telemetry data to provide a complete data set. After this, the data are edited, checked for errors, and coded to indicate any special conditions. Water level data are converted to discharge using the grade control structure ratings.

The goal of any data collection system is use of the data for some benefit. To facilitate that use, the data which have been collected, converted, and edited are stored in a data management system. This system is composed of several data bases and supporting software.

Martin (1976) defines data base as "a collection of interrelated data stored together with controlled redundance to serve one or more applications in an optimal fashion; the data are stored so that they are independent of programs which use the data; a common and controlled approach is used in adding new data and modifying and retrieving existing data within the data base." Two of the concepts in Martin's book are guiding development of the Goodwin Creek data bases. These are the concepts of logical and physical independence of data. The concept of logical data independence means that different users can see different logical organization of the data without requiring different actual logical organizations. This allows new programs and modifications of old ones to see different data organizations. Thus the data requirement for one program can change without disrupting data organization for other programs. The concept of physical data independence means that change in how the data are stored will not affect the overall logical organization of data or the application programs which use them.

Two broad categories of data have led to two different sets of data bases. One category is data which varies slowly with time or is considered time invariant. Examples include the locations of divides, drainage network, field boundaries, land use, soils, etc. These data are stored in a spatial information system with locations based on the Mississippi Plane Coordinate System. Definition of most features in this data base are by straight line segments or polygons. The second broad category is data which may vary rapidly with time. This category includes water level records, streamflow rate, precipitation, sediment transport rate, etc. The major characteristic of these data is many observations for each sensor at a location.

The data management system consists of the collection of data and the programs for retrieval and maintenance of the data. Some types of requests occur fairly frequently. Examples include availability, maximum, minimum, range, mean, standard deviation, etc. A user can obtain these directly

without the need for his own software. A user can also write his own application programs and retrieve the data for it.

The Vicksburg District Corps of Engineers has its own data base system, the Yazoo Basin Data Management System. The Goodwin Creek data can also be put into the Yazoo Basin system for use. The system of the laboratory is designed and oriented toward a small area, an area of a few square miles, while the Yazoo Basin System is designed to handle data for hundreds of square miles.

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